Shifting the norm - towards effective mixed mode buildings

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ABSTRACT

A mixed mode of operation, where supplementary air-conditioning is used only when indoor conditions ride outside the acceptable comfort range, can reduce the carbon footprint of the building. The paper uses four post occupancy studies of mixed mode building, two each from Australia and India to investigate successes and pitfalls. All four buildings succeeded in integrating a mixed mode of operation at a tectonic level, but feedback from the occupants was varied. The study showed that occupants can be forgiving of minor discomforts when other positive attributes are included, but the risk to performance is intensified when occupants perceive very little adaptive opportunity or problems are not rectified quickly. It identified a tolerance of higher temperatures in the Indian mixed mode buildings in contrast to the Australian experience where narrow limits serve to further entrench an expectation for air-conditioning and generate an energy impost. The findings of this paper question year round air-conditioning and challenge designers to rethink spatial and environmental opportunities in the context of the changing workplace when shifting the norm towards effective mixed mode buildings

INTRODUCTION

As workplaces in developing countries such as India are designed to the standards of contemporary western workplaces, year round air-conditioning (AC) operated within a narrow temperature range is fast becoming entrenched as the primary means for environmental control. Coupled with the rapid increase in office floor space, this trend is expected to fuel India's soaring demand for electricity unless serious measures are introduced to counter the energy-intensive approach (Thomas et al, 2010). On the other hand, studies have shown that a mixed mode of operation, where supplementary AC is used only when indoor conditions ride outside the acceptable comfort range, has the potential to drastically reduce the energy and carbon footprint of the building whilst satisfying comfort requirements (Brager, 2006; Leaman & Bordass 2001). Despite its benefits to both developed and developing contexts, a mixed mode of operation remains poorly understood and the uptake remains low. Furthermore its design and implementation is not without challenges. Drawing on feedback from post occupancy studies of mixed mode buildings in Australia and India, the paper will discuss why some buildings work well and others don't and what lessons can be learnt towards their effective implementation.

STUDY APPROACH

A post occupancy evaluation methodology noted for its ability to provide vital feedback on building performance and occupant satisfaction (Bordass et al, 2001, Vischer, 2007) is used to analyse four mixed mode buildings –two each in Australia and India-and all recognized examples of sustainable architecture. The Australian buildings (A-AUS, Sydney; and B-AUS, Melbourne) are located in a temperature climate characterized by warm/hot summer and cool winters, while the Indian buildings (C-

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IND, Delhi and D-IND, Gurgaon) are located in the relatively more challenging composite climate of the National Capital Region characterized by long hot summers, a humid monsoon, and dry cool winters.

The study approach includes a review of project information, site visits, interviews with key stakeholders (owner/developer, design team, and building manager) and a survey of building occupants to develop a context specific rich narrative of building performance. The Building Use Studies (BUS) Workplace Questionnaire Survey (paper based) was used to elicit the occupants' experience during their time in the building. Used in over 500 buildings worldwide including Australia and India, the survey covers 63 variables ranging from environmental comfort, user control, and design to perceived productivity and health. The survey was administered after at least one year of occupancy in three of the study buildings and nine months in C-IND. This ensured that occupants had experienced the full range of seasonal variation in the building, while overcoming any "Hawthorne effect" (Landsberger, 1958) associated with the short-term improvements arising from the novelty of introduced changes.

This paper also draws upon data collected as part of a thermal comfort field (TCS) study (after deDear & Brager, 1998) towards the development of the India Model for Adaptive Comfort (IMAC) (Manu et al, 2014 forthcoming) with particular focus on the occupants' response to thermal sensation, acceptability and office comfort as experienced "right here, right now" in buildings C-IND and D-IND.

The pertinent outcomes for each building are discussed in relation to design approach, building attributes and environmental control strategies below. Broader lessons from these studies as well as other implications for mixed mode buildings drawn from the literature and the author's experience of other buildings in both countries/contexts are discussed later in the paper. Sectional drawings of the four study buildings are provided in Figure 1, and relevant BUS and TCS data in Tables 1 and 2 respectively.

POE STUDIES FOR FOUR MIXED MODE BUILDINGS

Building A-AUS, Sydney

Completed in 2001, this 2000m^2 owner occupied office building accommodates 120 employees. The building has been credited (Thomas & Hall, 2004) as an early example where client commitment to sustainable design was matched by a development process in which tangible environmental criteria considered at project inception enabled the building to meet its energy targets. The building design is driven by a passive stack ventilation system that serves three of its four floors. Air is drawn across the narrow 15m floor plate through louvers on the south façade and exhausted through the solar chimneys on the north. A high level of tectonic integration is evident - an external screen of corten steel louvers provides sun-shading and security to the high performance glass facades and its openings, while the solar chimneys are detailed within the space between the twin blade columns. Supplementary AC via a variable refrigerant (VRV) system is ducted along the perimeter to maximize exposure of thermal mass in the concrete ceiling. The switch between passive (stack ventilation) and AC modes is controlled via a building management system (BMS). The acceptable temperature range was set to 19-25°C with an expectation of a greater tolerance in a mixed mode building compared typical AC workplaces.

Although the building achieved a strong 4.5 star ABGR energy performance[1], the occupant feedback in the BUS survey (Table 1) was disappointing. Occupant perception of excessively hot temperatures and the lack of adequate airflow resulted poor scores for temperature and air. This was traced to an erratic temperature and ventilation control system driving the louvers and excessive overheating on the upper floor (which was not linked to solar stack) compounded by a low perception of control when things were not working. Following complaints the set-points were narrowed to 20-24°C. Occupants also raised noise concerns which were caused in part by a lack of alternate break out spaces in an open plan environment and aggravated by the highly reflective surfaces of the exposed concrete ceilings. This exacerbated occupants' dissatisfaction and served to drive down scores for overall comfort, design, and perceived productivity and health. The study highlights that buildings that perform poorly from the occupants' perspective have a negative impact on their ability to do work

[1] ABGR is the former name for National Australian Building Environmental Rating Scheme (NABERS) energy rating system in Australia. In 2002, no building as large as Building A-AUS had realized the top 5 star rating achievable at the time.

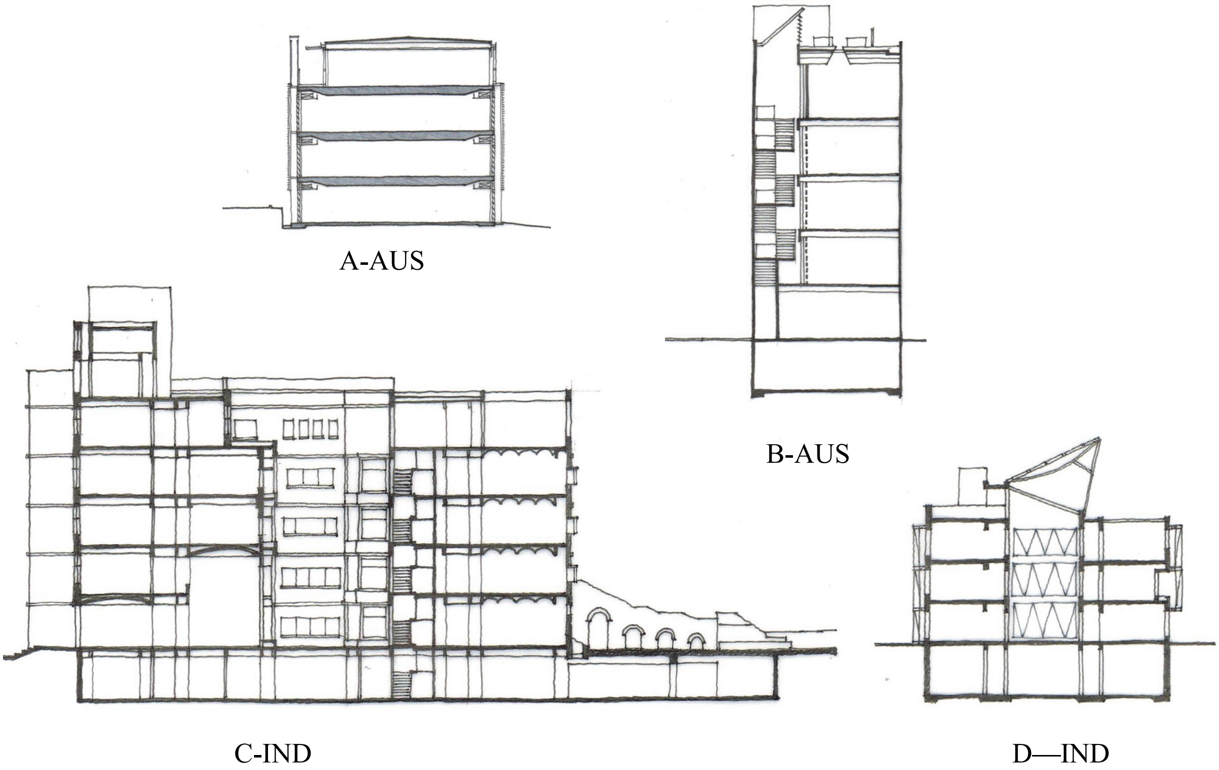

Figure 1 Cross sectional view of study buildings

Building B-AUS, Melbourne

Building B-AUS (Thomas and Vandenberg, 2007) was fully refurbished between 2004 and 2005 to provide 1200m^2 of office accommodation in a block constrained by its 10m x 55m footprint and glazed openings only on its shorter edges. The key architectural invention was to remodel the existing stair (alongside one of the 55m long party walls) into a light well and thermal stack for passive ventilation through the floor plate, changing the dynamics away from the lifts and constant AC. The office spaces are designed to operate in a 19-25°C temperature range during occupied hours, with a BMS controlling the switch over to the fan coil units in the ceiling, a night purge strategy to pre-cool the thermal mass inherent in the exposed concrete ceilings.

As seen in Table 1, the building recorded a level of high user satisfaction, and mean scores of survey responses for temperature, air and overall comfort are significantly better than both scale midpoints and BUS benchmarks. The high ratings for environmental aspects are influenced by the building management strategy whereby temperature, humidity, daylight and lighting levels, air quality and occupation are all monitored by the BMS, and appropriate responses are initiated by the building manager if things go wrong. This has ensured that early problems such as incorrect set-points in winter and a night-purge system which was operating regardless of outside temperature, were quickly rectified. Consequently, even though users perceived a low level of personal control over their environment, this had little impact on their ratings for overall comfort. The occupants also rated the building highly for its design, facilities, formal and informal meeting spaces, space utilization and perceived health and productivity. The building achieved a 6 star Green Star Office Design rating and its low energy design has consistently returned a 5 Star NABERS Energy rating since completion.

Building C-IND, New Delhi, India

This 3100m^2 building is head office to a non-governmental organization and was designed in close consultation with the owner occupant client group to prioritise sustainability. C-IND was awarded a LEED platinum rating and emphasizes low embodied energy materials, local construction methods and passive design to minimize operational energy. The design (Lall, 2010) integrates narrow office floor plates and a series of unconditioned spaces around a sheltered courtyard. Exposed vaulted ferro-cement ceilings and insulated fly ash cement block walls serve to stabilize internal temperatures. The structural system also integrates the air distribution channels - conditioned air is delivered at floor level through the U-shaped internal columns and returned through the hollow spaces between the vaulted ceiling elements. A range of fenestration treatments provide the occupants with a high degree of control over sun, daylight and natural ventilation. Occupants also have control over electric lighting and ceiling fans. In the original design, the building was intended to operate in a 100% passive mode from the end of September to early March, with the understanding that winter mornings would be colder than deemed comfortable. The "active-cooling" of this mixed mode building was originally designed as an innovative 2 stage hybrid Air conditioning system with evaporative cooling as the primary mode over the dry summer (March to June), and a second stage of cooling using mechanical refrigeration for the humid months (July and August). This was not installed due to unforeseen logistics and funding barriers. The client organisation moved into the building in late 2011 and while the upper two floors were untenanted, the building remained without AC over the first summer. Subsequently a conventional AC system, capable of providing heating and cooling to Levels 1 and 2, was installed at the start of the monsoon season.

Table 1. Summary of BUS Survey Results for Study Buildings

	Building A-AUS Sydney n=59, N=120			**Building B-AUS Melbourne** n=26, N=30			**Building C-IND New Delhi** n=44, N=75			**Building D-IND Gurgaon** n=58, N=90		
Benchmark dataset used for comparison	Australian benchmark 2003			Australian benchmark 2006			International benchmark 2013			International benchmark 2013		
Variable	**Score**	**% dissat**	**Result**	**Score**	**% dissat**	**Result**	**Score**	**% dissat**	**Result**	**Score**	**% dissat**	**Result**
Air In Summer	3.1	66%	Worse	5.6	11%	Better	3.9	39%	No diff	5.4	7%	Better
Air In Winter	3.4	60%	Worse	4.4	40%	No diff	4.8	16%	No diff	5.7	5%	Better
Air In Monsoon							4.7	12%		5.3	0%	
Temperature In Summer	3.2	58%	Worse	5.4	10%	Better	3.1	64%	Worse	5.4	12%	Better
Temperature In Winter	3.4	55%	Worse	4.4	31%	Better	4.3	15%	No diff	6.0	1%	Better
Temperature In Monsoon							4.8	20%		5.4	4%	
Lighting	5.1	14%	No diff	6.0	8%	Better	6.0	0%	Better	6.2	0%	Better
Noise	3.4	60%	Worse	5.1	15%	Better	5.2	11%	Better	5.6	9%	Better
Comfort Overall	3.6	46%	Worse	5.7	12%	Better	5.1	7%	No diff	5.6	1%	Better
Productivity (Perceived) %	-13.5	46%	Worse	6.0	4%	Better	2.8	36%	No diff	11.7	14%	Better
Health (Perceived)	3.1	56%	Worse	4.7	4%	Better	4.7	6%	Better	5.1	2%	Better
Design	3.7	46%	Worse	6.3	4%	Better	5.8	2%	Better	6.4	0%	Better
Do Facilities Meet Needs?	4.2	37%	No diff	5.9	8%	Better	5.5	4%	Better	6.0	1%	Better
Control Over Cooling	1.8	90%	Worse	2.4	73%	No diff	2.6	65%	Worse	2.7	62%	No diff
Control Over Heating	1.8	91%	Worse	2.4	73%	No diff	2.5	67%	Worse	2.5	66%	Worse
Control Over Lighting	1.7	90%	Worse	4.0	42%	No diff	5.8	5%	Better	4.4	31%	Better
Control Over Noise	1.9	89%	Worse	2.6	65%	No diff	3.9	33%	No diff	3.4	47%	No diff
Control Over Ventilation	2.0	86%	Worse	2.0	81%	Worse	4.9	20%	Better	3.3	54%	No diff
Forgiveness	0.99		**No change**	1.10		**Forgiving**	1.10		**Forgiving**	0.97		**No change**

n = number of respondents; N = number of occupants.
Each variable above is rated on a 7-point A type scale (1 is worst, 7 is best) with the exception of perceived productivity rated on a 9-point scale.
% dissat refers to percentage of dissatisfied respondents - based on those rating the variable as 1, 2 or 3 on the 7-point A type scale.
Result indicates if the mean building score is significantly Better or Worse or No different to the mean of the corresponding benchmark dataset.
Forgiveness is a measure of tolerance and is calculated as Comfort Score/Average of scores for Temperature, Air, Noise, and Lighting
If this ratio is greater than 1, it means occupants are forgiving.

The results of the BUS survey administered in August 2012 indicate user satisfaction is better or no different to both scale midpoints and BUS benchmarks for most variables (Table 1). Unsurprisingly, the absence of active cooling in summer yielded the worst results for overall temperature conditions in summer with 58% dissatisfied and 48 % rating the building as too hot. While overall conditions were rated no different to the benchmark for winter, 49% of the occupants felt the conditions were on the colder side of neutral. The TCS surveys (Table 2) reinforce this experience for summer (avg_ash=+1.7, 65% rating conditions as unacceptable) and winter (avg_ash=-1.0, 53% rating conditions as unacceptable) in weeks when the 7 day running mean (out7day_ta) was 40.6°C and 18.4°C respectively. An interesting finding is that occupants at C-IND are more “forgiving” in that their overall (BUS) and seasonal (TCS) ratings for office comfort are higher than would have been predicted by scores for temperature, lighting, air and noise. This can explained by a number of positive features in the overall design, and is substantiated by the high occupant satisfaction with lighting, daylight, noise, control over lighting and ventilation, design, work facilities and perceived health.

While a full energy monitoring of C-IND was not undertaken, the TCS survey measurements provide a glimpse of the moderating influence of the building envelope in extreme summer. With no supplementary cooling in play, the spaces maintain indoor operative temperatures (avg_top= 36.2°C) around 7 degrees less than T_{max} of 43°C and at par with T_{min} of 36°C. Likewise in the absence of supplementary heating in winter, the building just manages to maintain operative temperatures (all measured between 9:30am &12noon) at 17.9°C close to the 7 day running mean (out7day_ta) of 18.4°C.

Table 2. Selected TCS Survey Results for Indian Study Buildings

			Field Measurements and derived parameters								*Field Survey*			*Calculated Indices*		
	Survey month/ year	Num -ber of votes	Mean indoor air temper-ature (°C) **avg_ta**	Mean indoor radiant temper-ature (°C) **avg_tr**	Mean indoor relative humid-ity (%) **avg_rh**	Mean indoor air-speed (m/s) **avg_ vel_a**	Mean metabo lic activity (met) **avg_ met**	Mean insula-tion chair + clothing (clo) **avg_ insul**	7 day outdoor running mean (°C) **out7 day_ta**	Mean indoor opera-tive temper-ature (°C) **avg_top**	Mean ASHRAE thermal sensatio n vote (+3 hot; -3 cold) **avg_ash**	Thermal accepta bility % rating unacc-eptable **tsa_ dissat%**	Mean Office Comfort Score (1; 7) **avg_ comf**	PMV (+3 hot; -3 cold) **avg_ pmv**	PPD (%) **avg_ ppd**	*Indicative results for Neutral Operative Temper-ature* ***T_{op}neut (LR)***
BUILDING C-IND																
Summer	Jun 12	66	36.2	36.3	43%	0.5	1.2	0.8	40.6	36.2	**1.7**	65%	4.3	**3.0**	100%	
Monsoon	Aug 12	45	26.9	27.3	62%	0.2	1.3	0.8	32.3	27.1	**-0.1**	3%	5.6	**1.1**	39%	*28.2*
Winter	Dec 12	52	17.9	17.7	52%	0.1	1.2	2.2	18.4	17.8	**-1.0**	53%	5.0	**0.5**	12%	
BUILDING D-IND																
Summer	Jun 12	55	26.1	26.4	43%	0.2	1.2	0.8	39.9	26.2	**-0.1**	13%	6.4	**0.6**	19%	*27.4*
Monsoon	Aug 12	62	25.2	25.6	60%	0.2	1.2	0.8	31.3	25.4	**-0.1**	5%	6.1	**0.6**	20%	*26.1*
Winter	Feb 12	64	24.1	23.6	38%	0.1	1.3	1.5	15.7	23.9	**0.1**	5%	6.0	**0.9**	24%	*22.4*

Data Source: IMAC Study (Manu et al, 2014 forthcoming).

– Office occupants’ response to thermal sensation *avg_ash* is recorded on a seven point ASHRAE thermal sensation scale (+3 hot; -3 cold)
– *tsa_dissat%* is the percentage of occupants rating ‘unacceptable’ for thermal acceptability on a binary scale (1 = unacceptable, 2 = acceptable)
– Office comfort (right here, right now) is rated on a 7-point A type scale (1 = uncomfortable to 7 = comfortable)
– The 7 day outdoor running mean *out7day_ta* is derived from weather station data.
– The average Predicted Mean Vote *avg_pmv* and predicted percent dissatisfied *avg_ppd* for each cohort are calculated from field measurements
– Neutral Operative Temperature *T_{op}neut (LR)* is derived by Linear Regression on Observed Sensation controlling for extrapolation outside observed range

Building D-IND, Gurgaon, India

Located approximately 35km from New Delhi, D-IND is designed to house multiple tenants, with a research institution as its primary owner occupant. The LEED Platinum rated building is designed to reduce energy demand by facilitating natural ventilation and glare free daylight and minimizing unwanted heat gains through narrow floor plates, sheltered courtyards, appropriate fenestration and insulation to the building envelope. Passive air flow through operable windows is aided by the stack effect in the light well. AC is provided when conditions are not conducive for natural ventilation using a displacement ventilation strategy whereby air is delivered at floor level and returned at ceiling level. Ducting is integrated with the internal structure and partitioning system to ensure air flow paths are not impeded and concrete ceilings remain exposed to the internal space. The AC system is only operated in the periods between March to September, and December to January. Although it is linked to a BMS, a highly experienced building manager onsite plays a proactive role in moderating the set points and hours of operation based on the use of ceiling fans (not accounted for by the BMS), time of day and season.

The BUS survey results show a high level of user satisfaction across all summary variables comfort variables (temperature air noise and lighting) as well as design, perceived productivity and health (Table 1) and bear out the efforts towards integrated design and occupant comfort. All TCS survey campaigns at D-IND occurred when the AC system was typically in operation. The results indicate a strong level of acceptance of thermal conditions (avg_ash in the range of -0.1 to +0.1, Table 2), with only 5-13% rating conditions as unacceptable. This satisfaction with overall temperature conditions is corroborated in the BUS study scores for temperature and air across all 3 seasons. Although perceived control over ventilation is rated no different to the BUS benchmark, occupants made full use of ceiling fans. For example, over two thirds of occupants had their ceiling fans switched on concurrently with AC at the time of the TCS summer survey. However on site interviews indicated occupants were less enthusiastic about opening windows to their office even in the mild season, citing dust and noise.

OPPORTUNITIES AND BARRIERS TO MIXED MODE BUILDINGS

A successful mixed mode building needs to maximize occupant comfort and mimimise energy use across both its modes of operation. This in turn is affected by inter-related considerations including user expectations for comfort, the manner in which that comfort is provided for under each mode, the extent of passive operation achieved, control strategies for change-over and occupant interaction, and the potential of the building fabric and systems to moderate comfort and energy in use.

A climate responsive approach to building design supported by committed clients, and skilled design team is a critical first step to ensuring **low energy outcomes**. This aspect is the well understood in the study buildings. Each goes beyond basic application of passive design principles to achieve a tectonic integration of building elements where each 'does more than one thing'. In a market where passive technologies are viewed as an add-on cost, strategies such as the merger of the structural and environmental control systems at A-AUS and C-IND or use of stair wells that allow, circulation, daylight and air flow at B-AUS and D-IND demonstrate the value in considering environmental control strategies at the inception of the design process to both building budget and operation. The efficiency of the building fabric and design is borne out in the actual energy efficiency performance ratings for A-AUS and B-AUS. While the aspirations of the hybrid AC system could not be realized at C-IND, both the C-IND and D-IND are excellent case studies of how designers can rise to challenges of considering appropriate technologies, local materials and skills and mitigating the overwhelming embodied energy associated with high performance glazing shipped across the seas.

Comfort expectation of the users and thermal set points play a key role in influencing the extent to which the building operates in either active or passive mode. As discussed in Thomas & Thomas (2010), lease agreements and guidelines for tightly controlled settings 22.5±1 °C entrench reliance on AC and pre-condition users to expect these conditions. Although both Australian buildings were originally designed to operate at 19-25°C, there is more to a mixed mode of operation than simply stipulating wider temperature bands. As seen in A-AUS, the risk to performance is intensified when occupants perceive very little control or adaptive opportunity and problems are not rectified quickly. The contrasting **proactive and user responsive approach to building design and management** as seen in B-AUS and D-IND, signals the importance of this approach for successful mixed mode buildings.

C-IND and D-IND are significant in that they buck the more recent trend of year-round 100% AC in contemporary workplaces in Delhi (Thomas et al, 2010) and operate a seasonal AC mode where systems are completely switched off in the mild season. Under this paradigm, two facts are noteworthy – (a.) There is a tacit acceptance of some level of discomfort that could occur in the mild season, but consistent discomfort (as seen in C-IND during the extreme summer conditions before AC was installed) is not acceptable. And (b.), occupants in these contemporary and well-appointed workplaces, who undertake professional, administrative and technical work, consistently demonstrate **a tolerance to much higher temperatures in the subcontinent even in the air-conditioned mode**. The actual thermal sensation (avg_ash, Table 2) is consistently reported cooler than predicted using the PMV-PPD model (avg_pmv) showing a tolerance of warmer temperatures. The emerging results suggest neutral operative temperatures for these particular buildings are 26-27°C in summer/monsoon and 22°C in winter – which is consistent with an adaptive model of comfort (deDear and Brager, 1998).

This brings us to **potential energy savings with mixed mode under different set-points**. Figure 2 shows simulation results (using EnergyPlus) for a 5zone building model under different set-points in Sydney and Delhi. The building envelope and internal load schedules are set to comply with local (ECBC for Delhi; BCA for Sydney). For simplicity, heating and cooling set-points were held constant throughout the year, and the model allows a free running mode whenever external conditions are conducive to maintain stipulated temperature ranges. The ranges tested were 19-25, 20-24, 20-26, 20-28, 22-26 and 22-28°C. With cooling energy being more than 90% of total energy, the discussion below focuses on the impact of varying the cooling set-point on an equator facing perimeter mid-level zone.

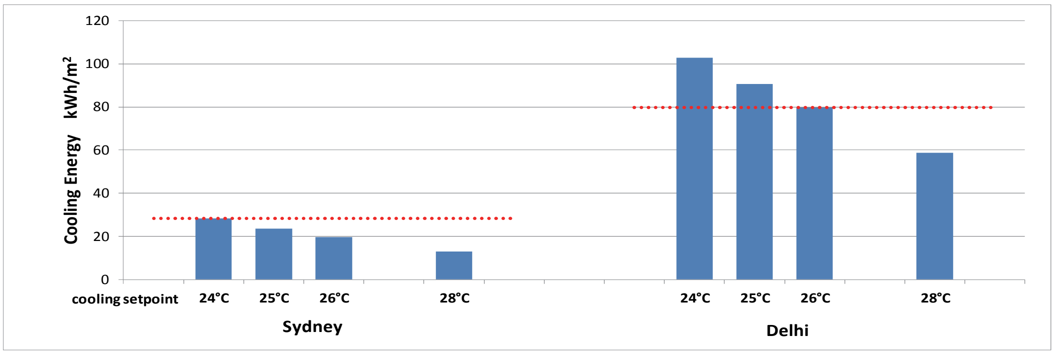

Figure 2 Predicted cooling energy at different cooling set-points for Sydney (north) and Delhi (south)

The results show cooling energy decreases by roughly 12-13% for every degree rise in the set-point temperature in both cities. This concurs with other studies (Ward &White, 2007). The change from the current baseline of 24°C for Sydney and 26°C for Delhi suggests the scale of savings possible. In the case of Sydney, it clearly shows savings of 17% and 31% of the cooling energy at 24°C if the set-point was raised to 25 and 26°C. The results for Delhi show a further 25% of savings would arise by raising the set-point to 28°C[2] from the current set-point, but more importantly we can see substantial increases to cooling energy of 14% and 29% if cooling set point was lowered to match western workplaces at 25°C or 24°C. It is the scale of such a shift that is concerning, given that the actual cooling energy for an office in Delhi is about three times the energy for an office in a more benign climate like Sydney.

TOWARDS EFFECTIVE MIXED MODE BUILDINGS

With respect to the Indian context, the study is a wakeup call to **question the fully air-conditioned approach for the subcontinent** – This is emphasized through the demonstrable tolerance of higher temperatures in the Indian buildings, the energy impost from lowering temperature set-points, and the western experience that narrow limits only serve to entrench air-conditioning. This is more urgent given that the projected increase of built floor space and the warmer climatic conditions will only exacerbate the dependence on fossil based energy. Clearly, it is necessary to harness local capacity for sensible design of mixed mode buildings that cater to India's contemporary workplace needs and shift away from climate rejecting air-conditioned buildings that mimic the worst of many "developed" countries.

In the Australian context, it is ironic (yet unsurprising) that the vicious cycle of air-conditioning and expectations for a narrow band of temperatures continuously negate the possibility of free running and mixed mode buildings despite the benign climatic conditions in cities like Sydney and Melbourne where the potential for such buildings is arguably higher. Here the challenge becomes "**how do we tease occupants out of the highly controlled work environments they have come to expect**?"

Across both contexts, designers need to **explore opportunities to combine mixed mode design with attributes that users like.** As seen in this study, while a lack of occupant control is not perceived as an issue when systems are responsive, occupants can be forgiving of minor discomforts when other positive attributes are included such as connection to the outdoor, daylight, flexible workspaces and amenities. The study also shows that increased adaptive opportunity tends to increase tolerance of a wider band of temperatures. These outcomes confirm other studies (Baker & Standevan, 1996, Leaman & Bordass, 2001 and Leaman et al, 2007), but more importantly they provide us with a "way –in". Rather than considering the office as a homogenous work environment with standardized conditions to be met at all times, an alternate approach would be to seek out functional areas that would benefit from fresh air, daylight etc. Until recently such areas isolated from central air-conditioning have formed only

[2] The 28°C corresponds to an upper limit of 2 degrees above a neutral temperature of 26C that would still deliver a 90% acceptability.

a small percentage of floor space (B-AUS, Drake et al, 2010). However as new ways of "activity based working" are promoted, a higher percentage of floor area is being devoted to break out spaces, café style work environments and flexible zones. As occupants are also encouraged to change location based on their activities, these spaces lend themselves to a mixed mode of operation with adaptive opportunity.

The findings of this paper challenge designers to rethink spatial and environmental opportunities in the context of the changing workplace when shifting the norm towards effective mixed mode buildings. A well designed mixed mode building that is conceptualized and operated from a user centered approach has the potential to drastically reduce the carbon footprint of the building whilst enhancing occupant satisfaction. It presents the opportunity to leap-frog the energy intensive paradigm of air-conditioned building when choosing the way forward for both developed and developing societies.

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